Aerosol-cloud interactions in the GMI: Current status and future directions

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photo: S.Lance

GMI and aerosol-cloud interactions: status

Currently accomplished

- Installed the GMI code at Georgia Tech SGI workstations.
- Began implementing aerosol-cloud interaction modules
  - ✓ The type of cloud-relevant information changes with the met fields used (DAO, GISS).
  - ✓ Currently using DAO.
  - ✓ Wrote basic routines to diagnose large-scale relative humidity and cloud fraction from met fields
  - ✓ Cloud properties are then calculated from parameterizations.
- Aerosol-cloud droplet parameterizations implemented
  - ✓ Boucher and Lohmann (1995) – empirical
  - ✓ Abdul-Razzak and Ghan (1998 and later) – mechanistic
  - ✓ Nenes and Seinfeld (2003 and later) - mechanistic

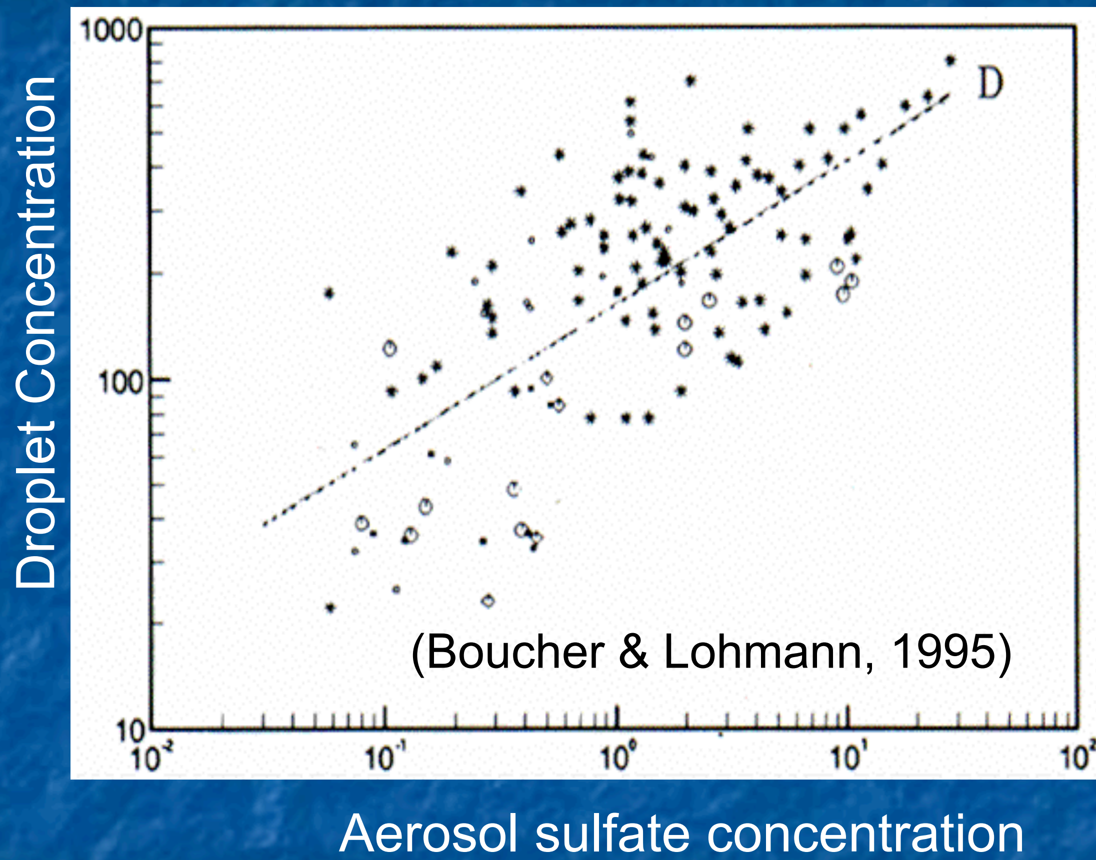
Empirical aerosol-drop parameterizations

Pros

- Simple to implement.
- Fast computation.

Cons

- Empirical
- No physical basis.
- Large uncertainty
- …

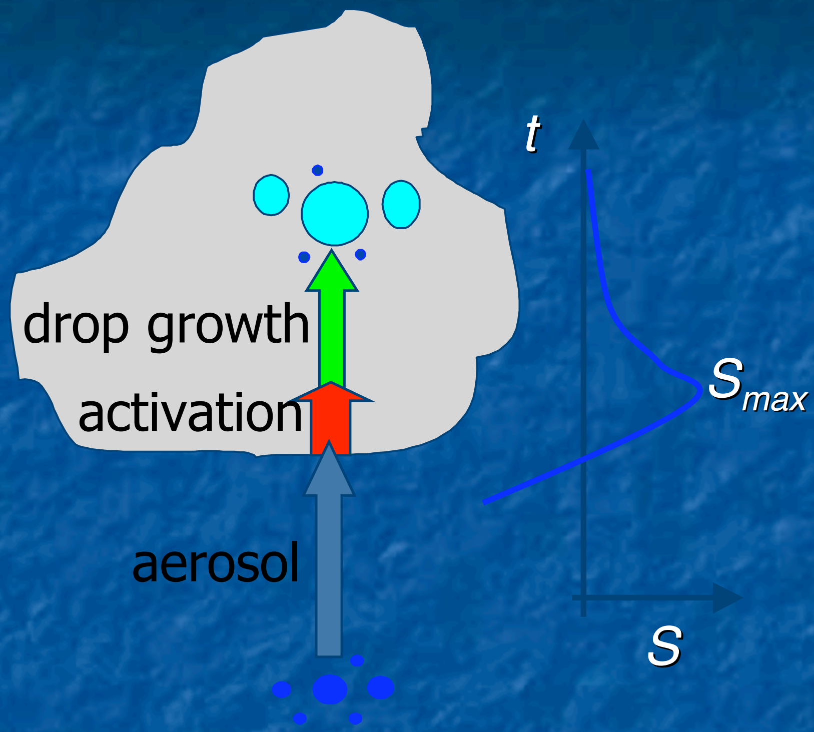


We use empirical correlations as a “benchmark”.

Mechanistic aerosol-drop parameterizations

Pros

- Explicit representation of aerosol chemistry and size distribution.
- Explicitly calculate droplet number and size distribution based on physical parameters



Cons

- Relatively slower
- Need for subgrid cloud dynamics (updraft velocity). These quantities are not available from GMI and must be inferred.

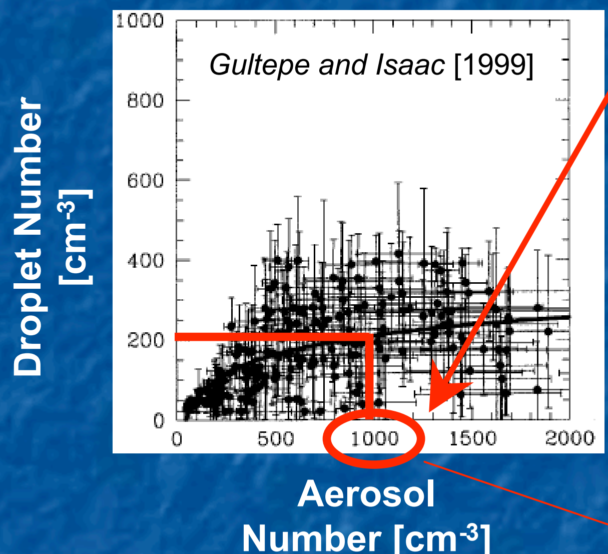
Updrafts are usually prescribed or diagnosed from large-scale TKE resolved in the GCM. The latter is not available in GMI.

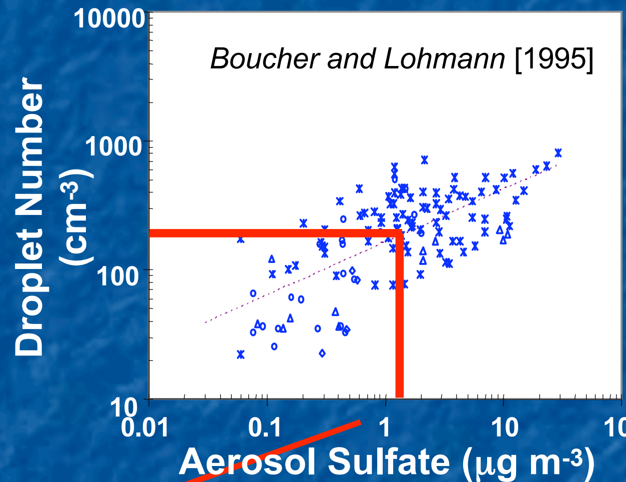
We also use an alternative proposed by Lance et al., JGR, (2004) to infer the updrafts from combination of empirical correlations.

Inferring in-cloud updraft velocity

Empirical correlations can be used to obtain "effective" updraft for use with mechanistic schemes.

Prescribed or Simulated Size Distribution from GCM

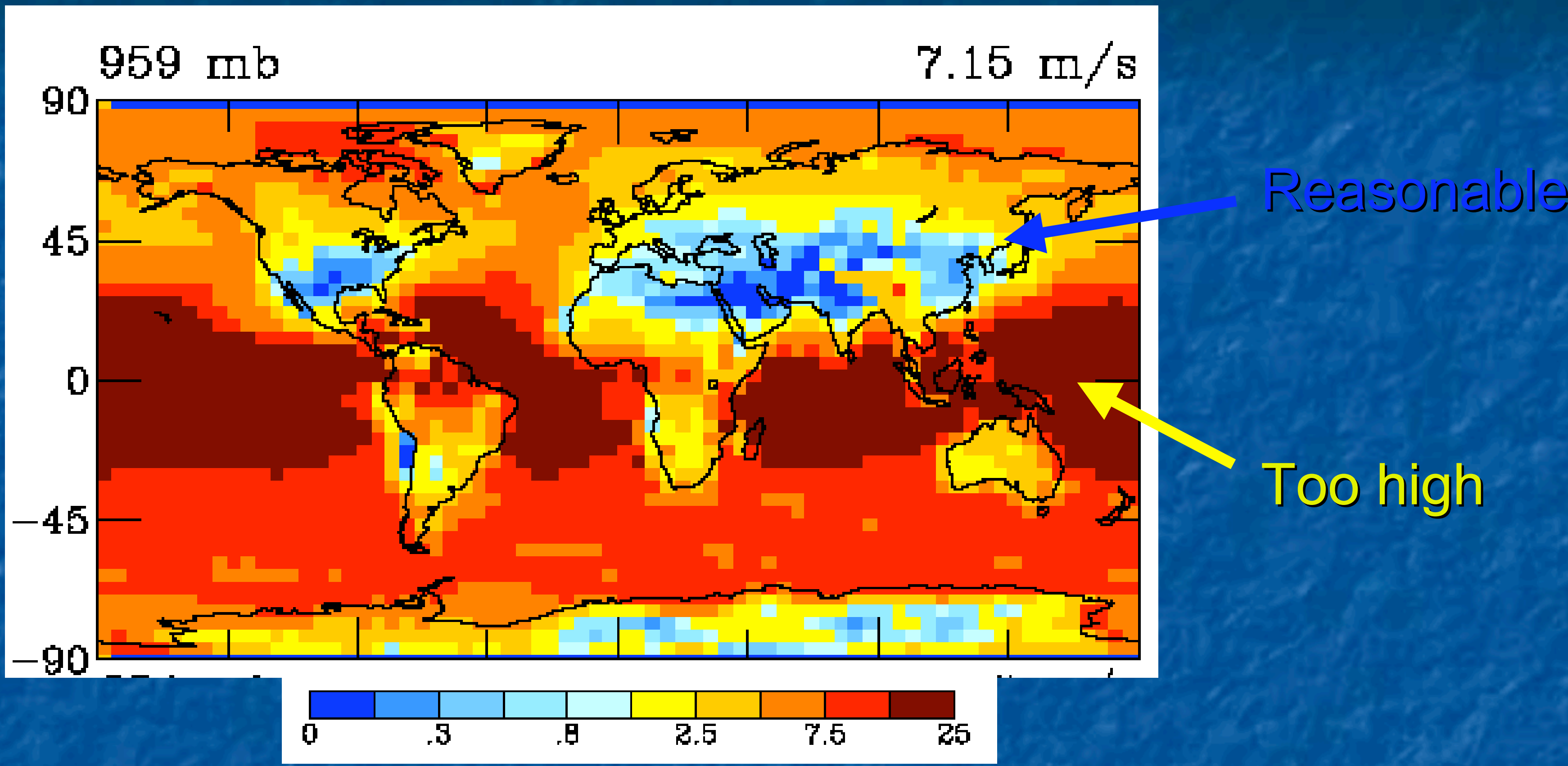




N_d, N_{total}, m_{so4} + Mechanistic Parameterization

Determine the "effective" updraft. This is then used as a "basecase" updraft for further perturbation experiments.

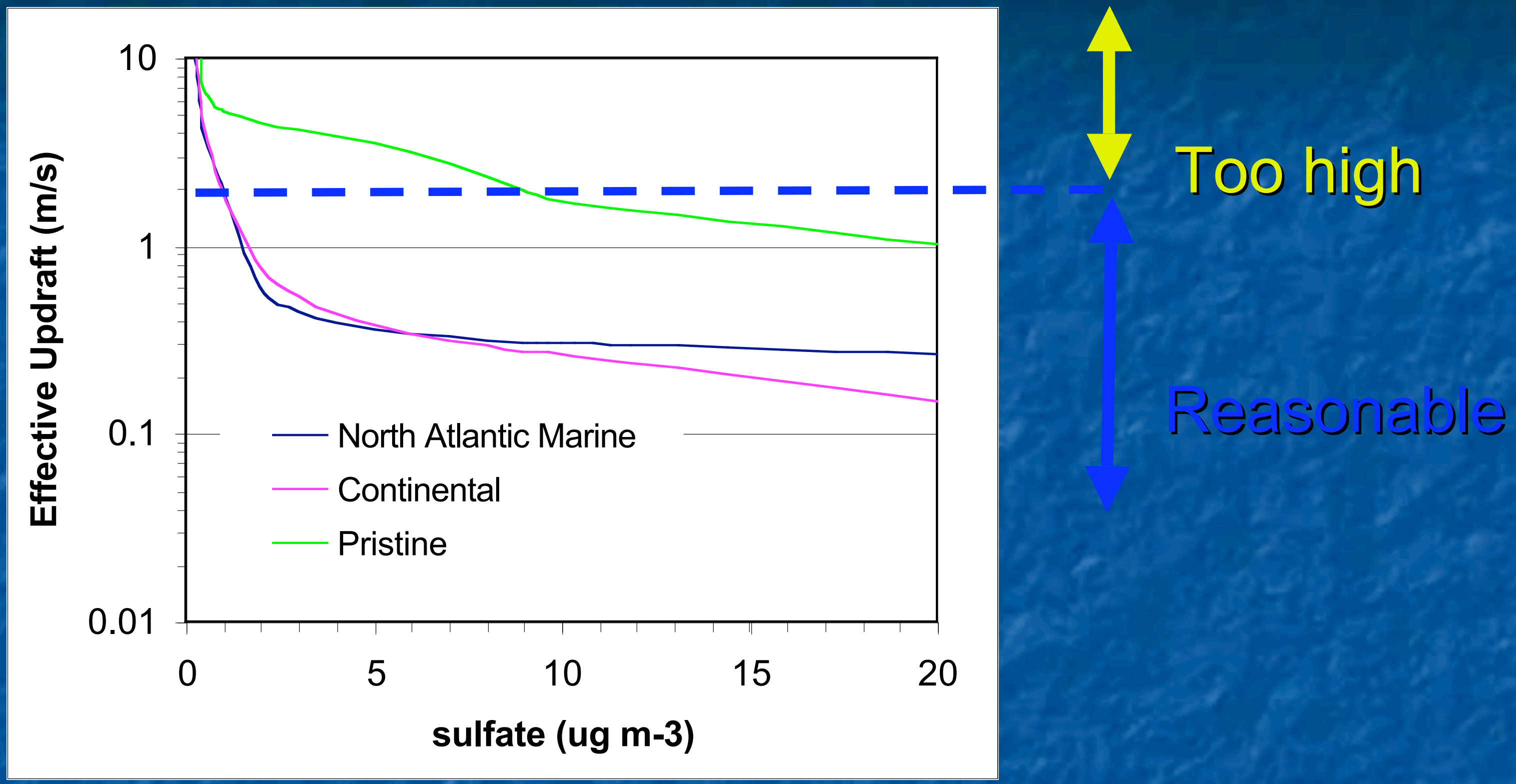
Inferring in-cloud updraft velocity: issues



Empirical correlations may yield unrealistic cloud dynamics.
The problem appears at marine/clean environments.
Polluted areas give “reasonable” updrafts

Nenes, *in preparation*

Inferred "effective" updraft velocity



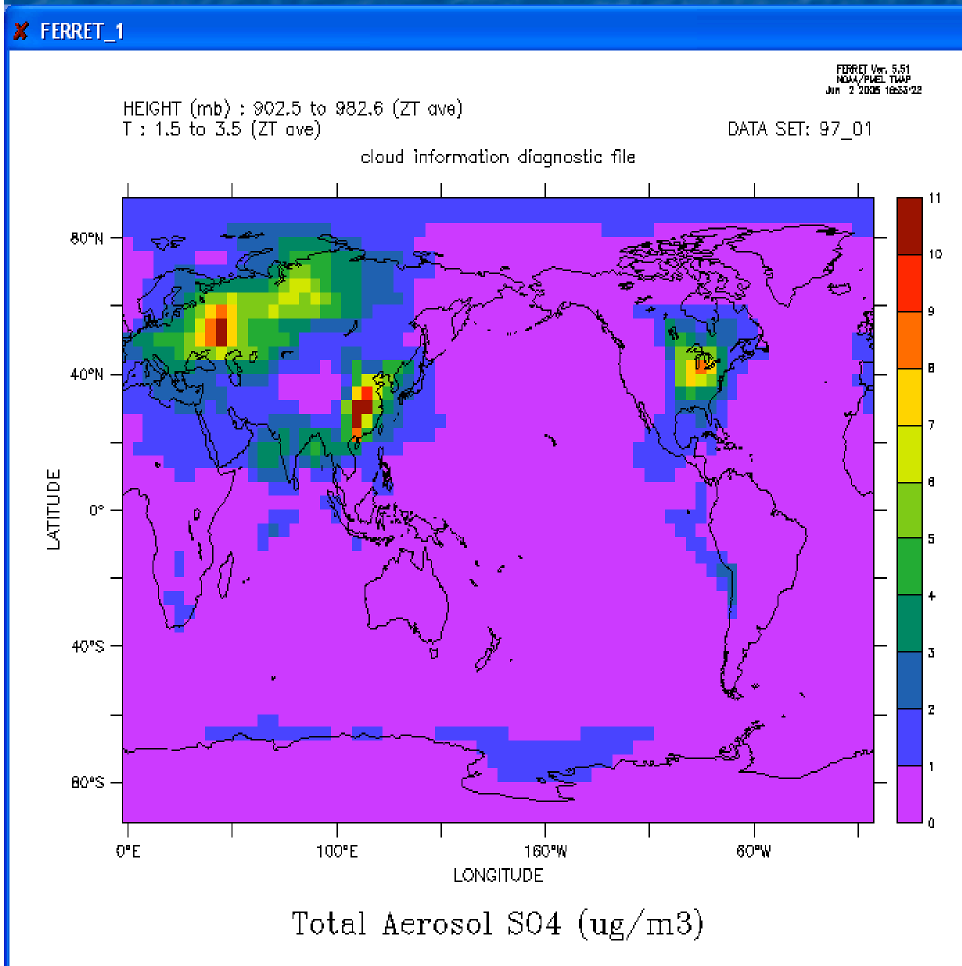
- Updrafts reasonable and insensitive to $[SO_4]$ when > 2-5 _g m^{-3} (good).
- Pristine (clean) environments always have higher updrafts. Not surprising; correlations were derived from polluted areas.
- **Set the max updraft to 2 m s^{-1}**

Nenes, *in preparation*

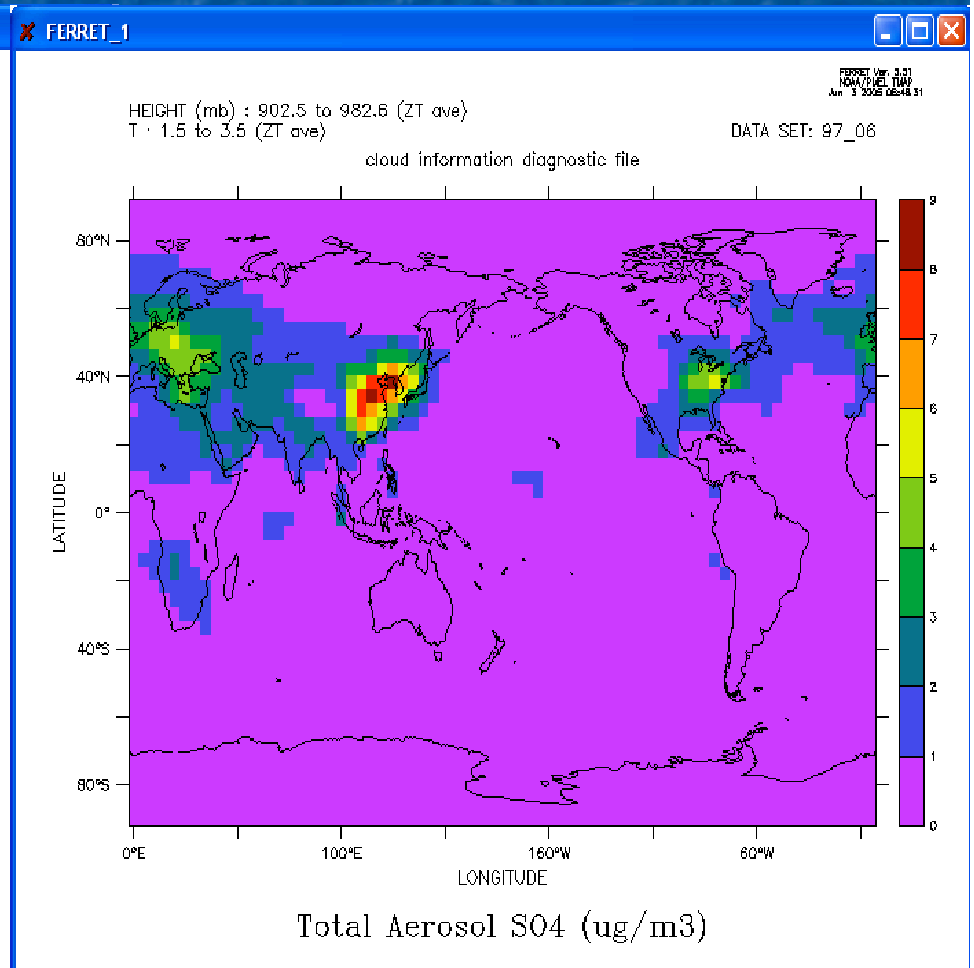
Aerosol-cloud interaction simulations in GMI

Input quantity: Aerosol Sulfate

January 1998



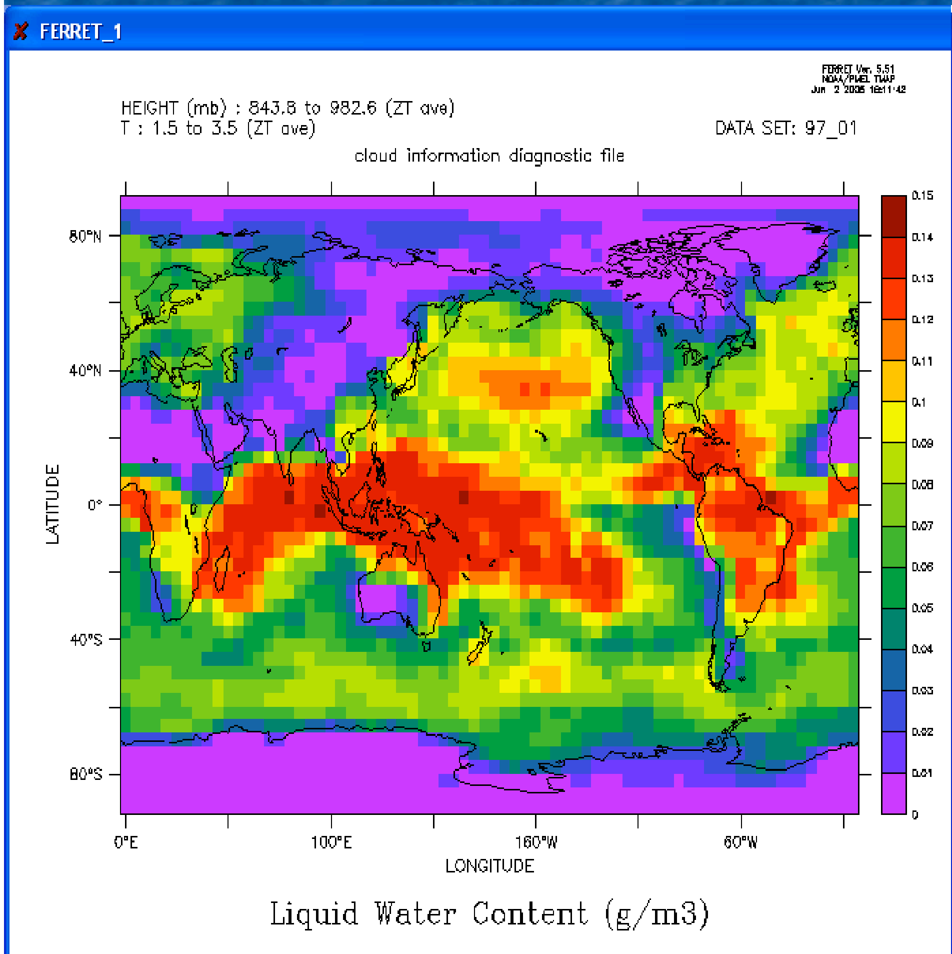
June 1997



Aerosol-cloud interaction simulations in GMI

Input quantity: Cloud Liquid Water Content

January 1998



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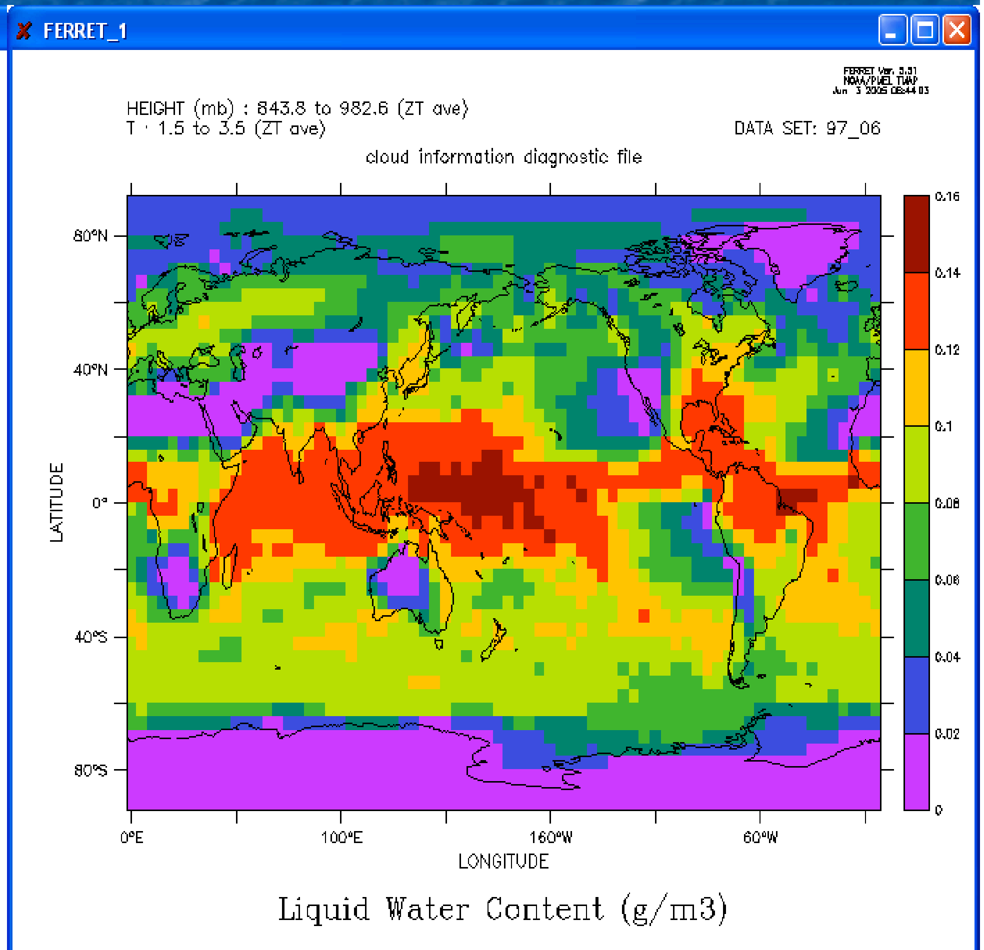
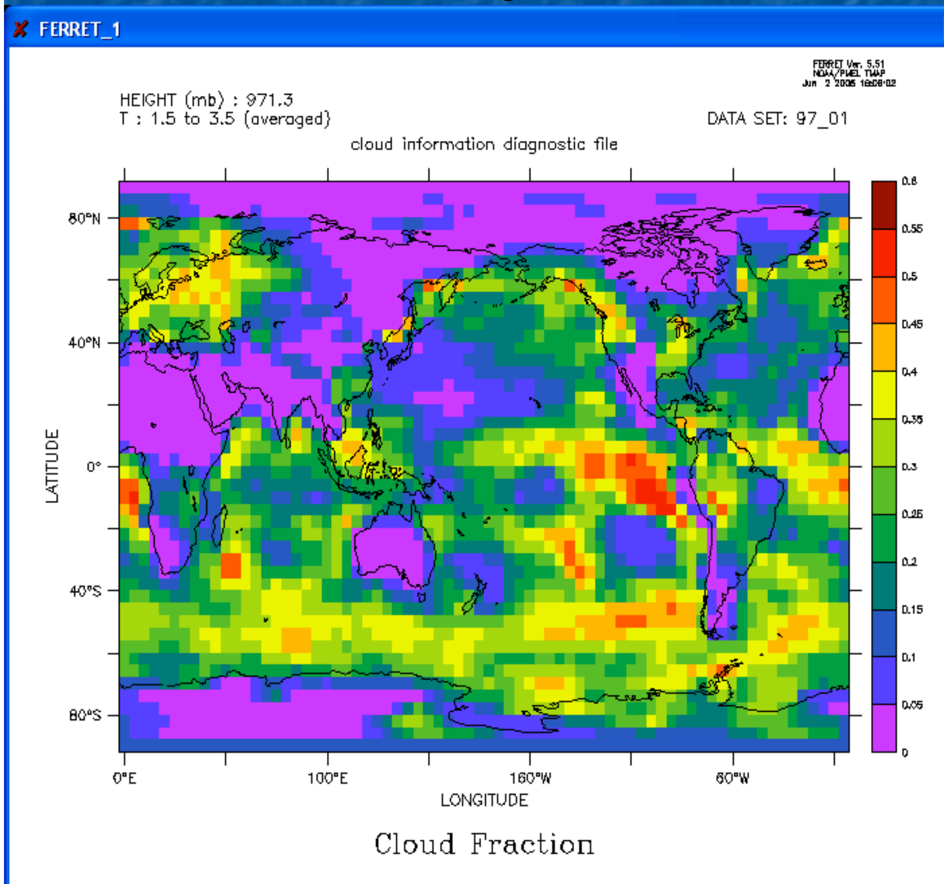


Met field used: DAO

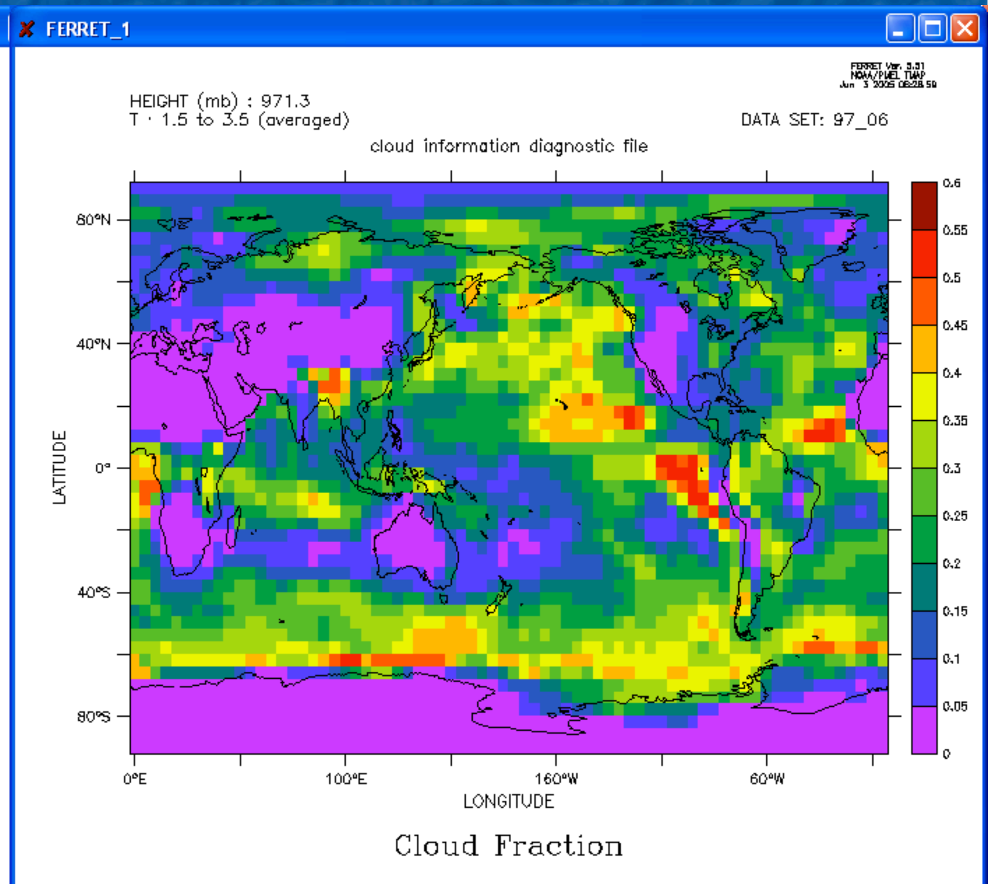
Aerosol-cloud interaction simulations in GMI

Derived quantity: Cloud Fraction

January 1998



June 1997

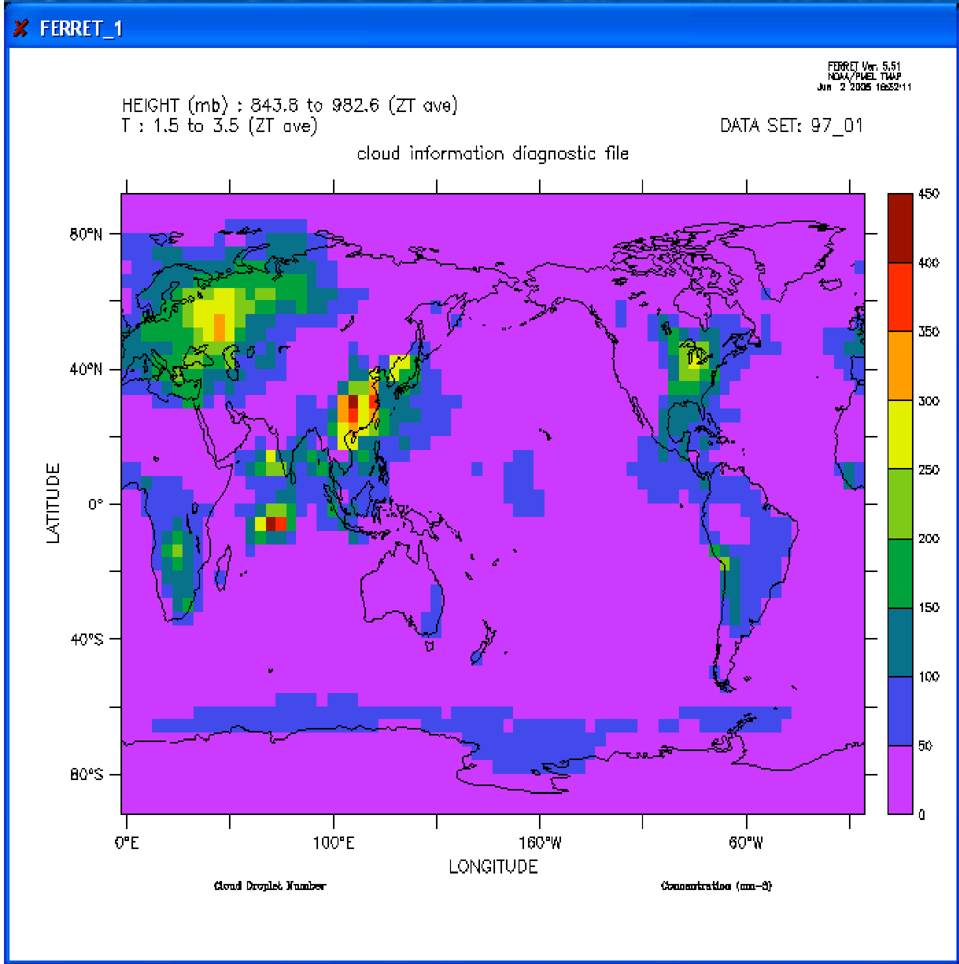


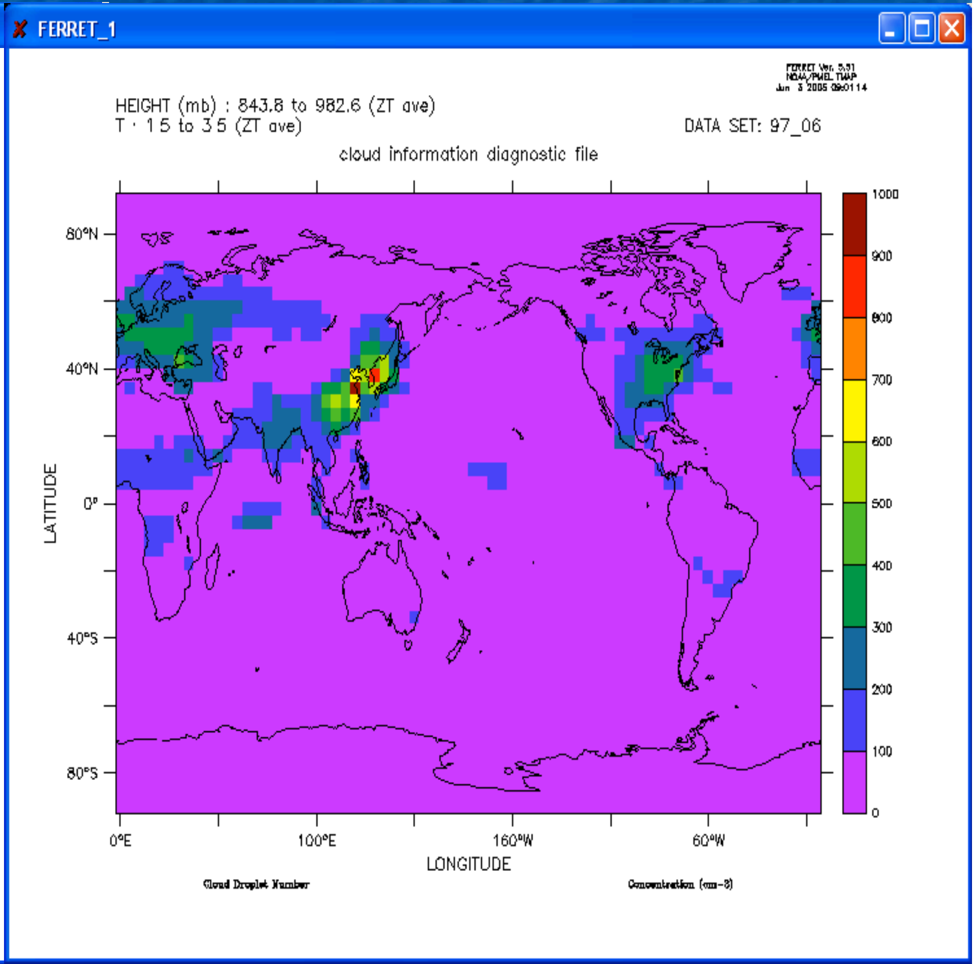
Cloud Fraction is diagnosed from grid-scale RH using Sundqvist scheme

Aerosol-cloud interaction simulations in GMI

Derived quantity: Cloud Droplet Number

January 1998 | **June 1997**



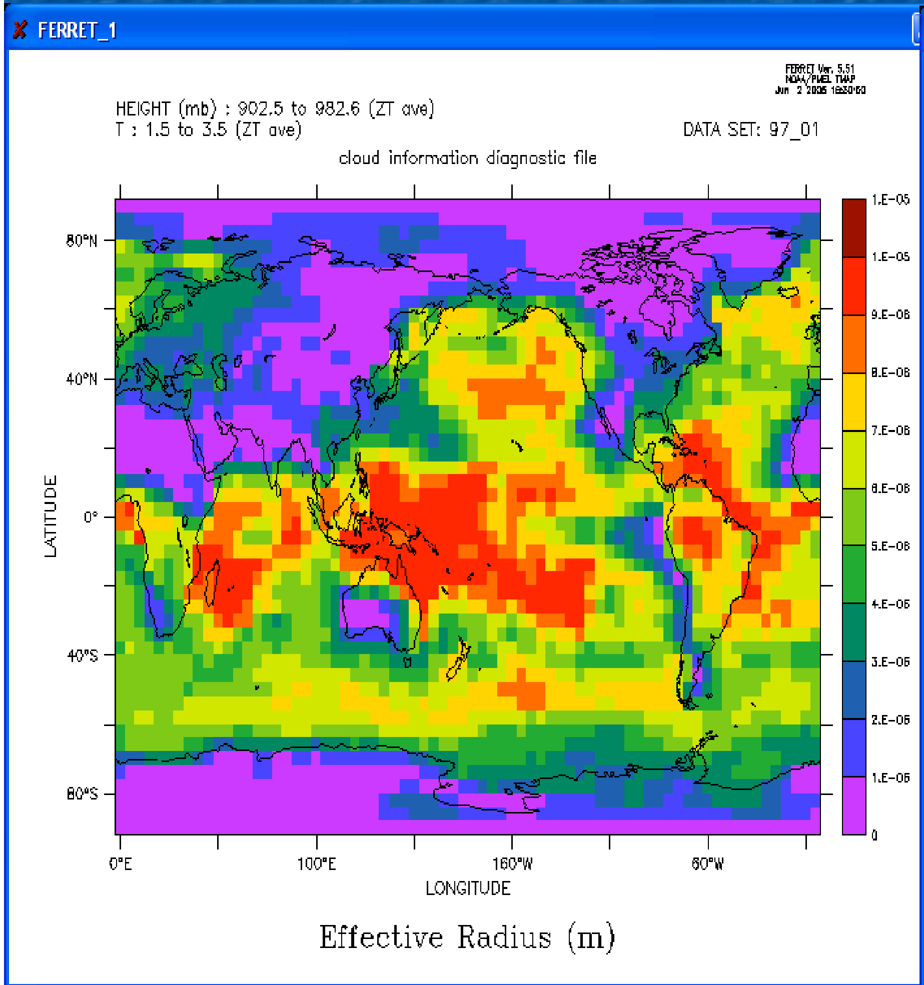


Boucher and Lohmann (1995) empirical parameterization is used.

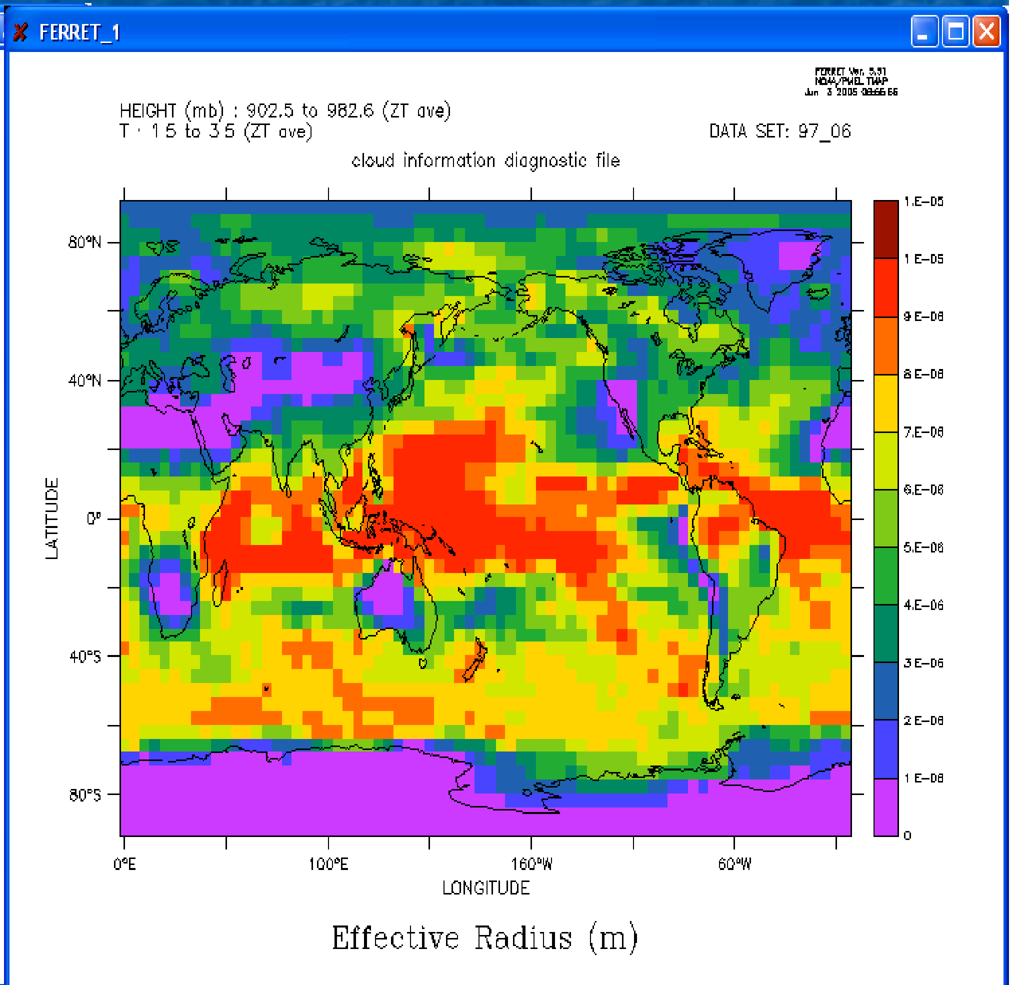
Aerosol-cloud interaction simulations in GMI

Derived quantity: Effective Radius

January 1998



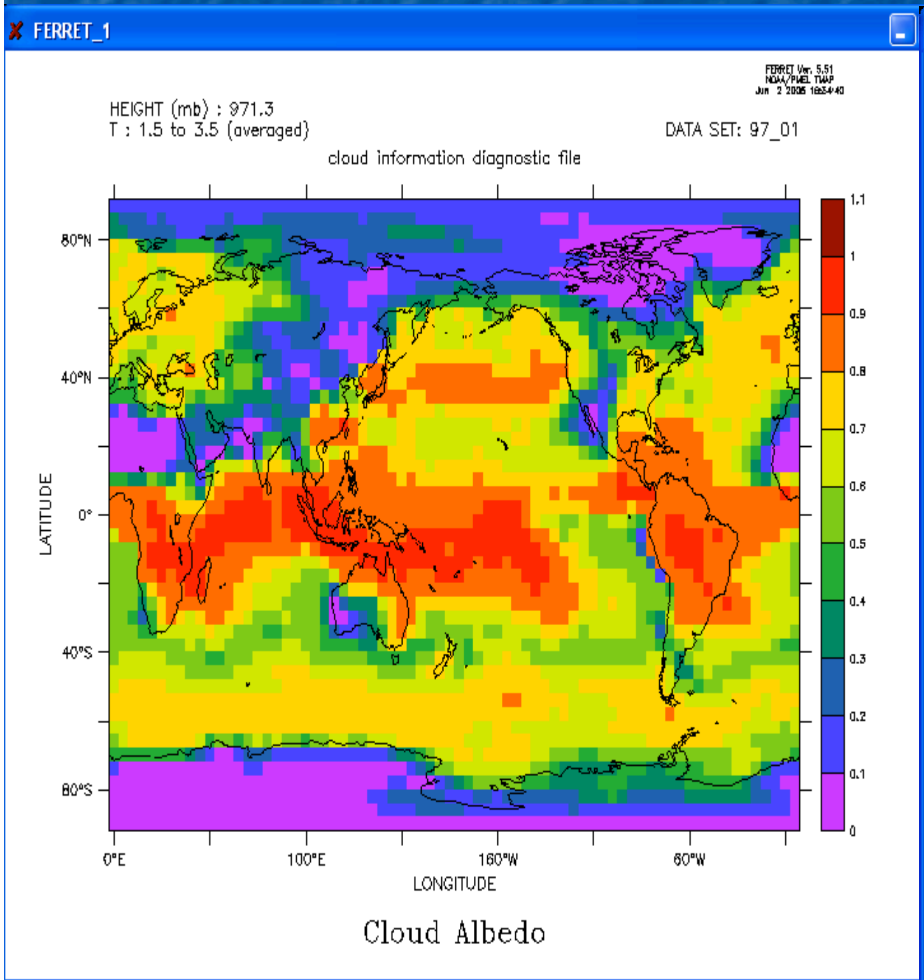
June 1997



Aerosol-cloud interaction simulations in GMI

Derived quantity: Cloud Albedo

January 1998



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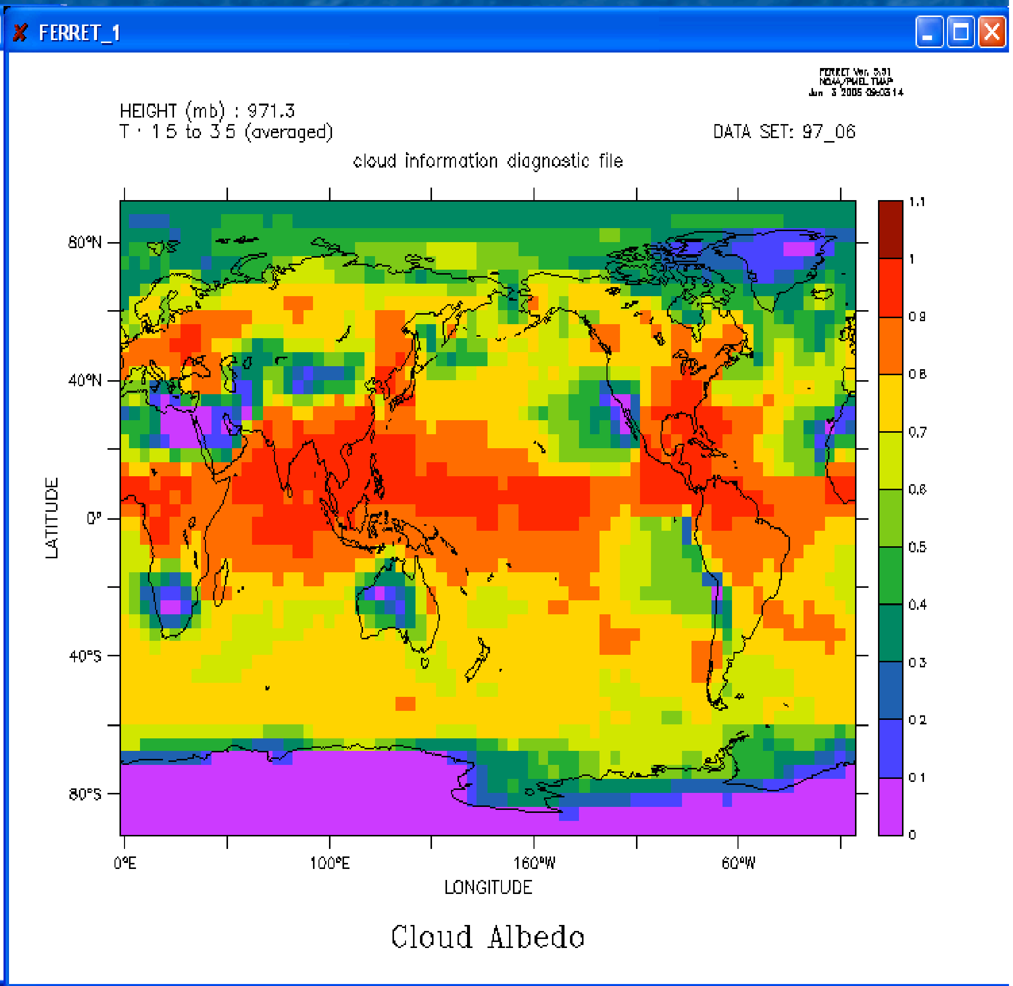


Short term "products" with GMI

Evaluate simulations

Make sure cloud effective radius and optical depth are reasonable.

Indirect forcing assessments

Perform an indirect forcing calculation, where the contribution of anthropogenic aerosol to cloud optical depth (and its forcing) is assessed.

Explicitly test sensitivity of indirect forcing estimates to:

- Met field
- Cloud droplet parameterization
- Aerosol mixing state
- Chemical effects (constrain using data obtained from field/lab experiments on CCN activation)

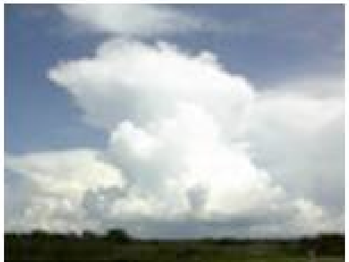
Short term "products" with GMI

Continue development of parameterizations

- Derived formulations for ***sectional*** (Nenes and Seinfeld, 2003) and ***lognormal*** (Fountoukis and Nenes, JGR, *in press*) aerosol.
- Included size-dependant mass transfer of water vapor to droplets which eliminated underestimation tendency in parameterized droplet number (Fountoukis and Nenes, JGR, *in press*).
- Explicitly can treat partially soluble organics that alter surface tension and accommodation coefficient (Fountoukis and Nenes, JGR, *in press*).
- Included the effect of condensable gases (Nenes, in preparation).
- Deriving formulations with entrainment and in-cloud chemistry.

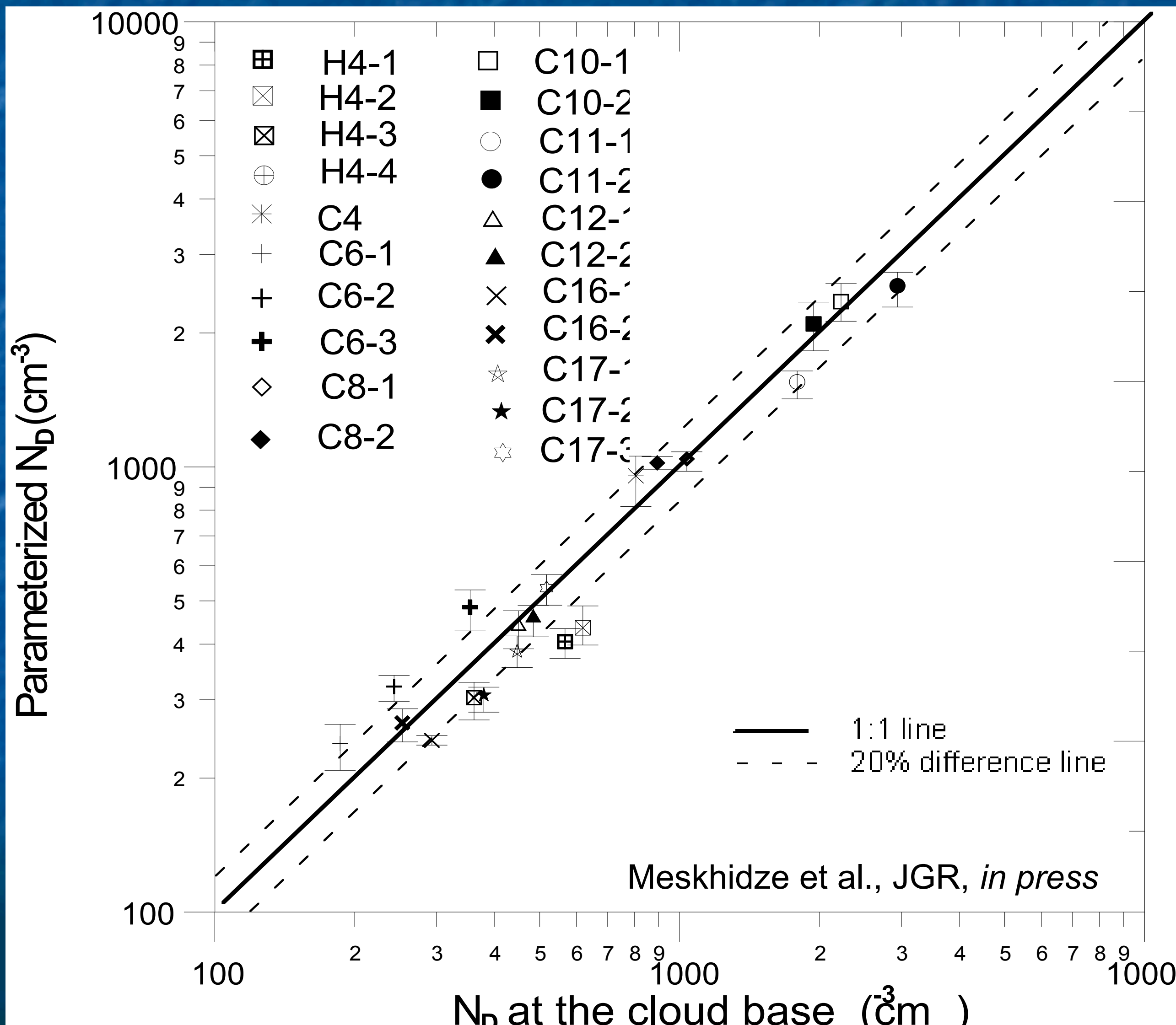
Continue *in-situ* evaluation of parameterizations

- Have three in-situ aerosol-cloud datasets for the evaluation, that cover climatically important cloud/aerosol types. Will get more this summer
- Use datasets to evaluate all parameterizations used in GMI



CRYSTAL-FACE Evaluation Shallow Cumulus

CIRPAS Twin Otter



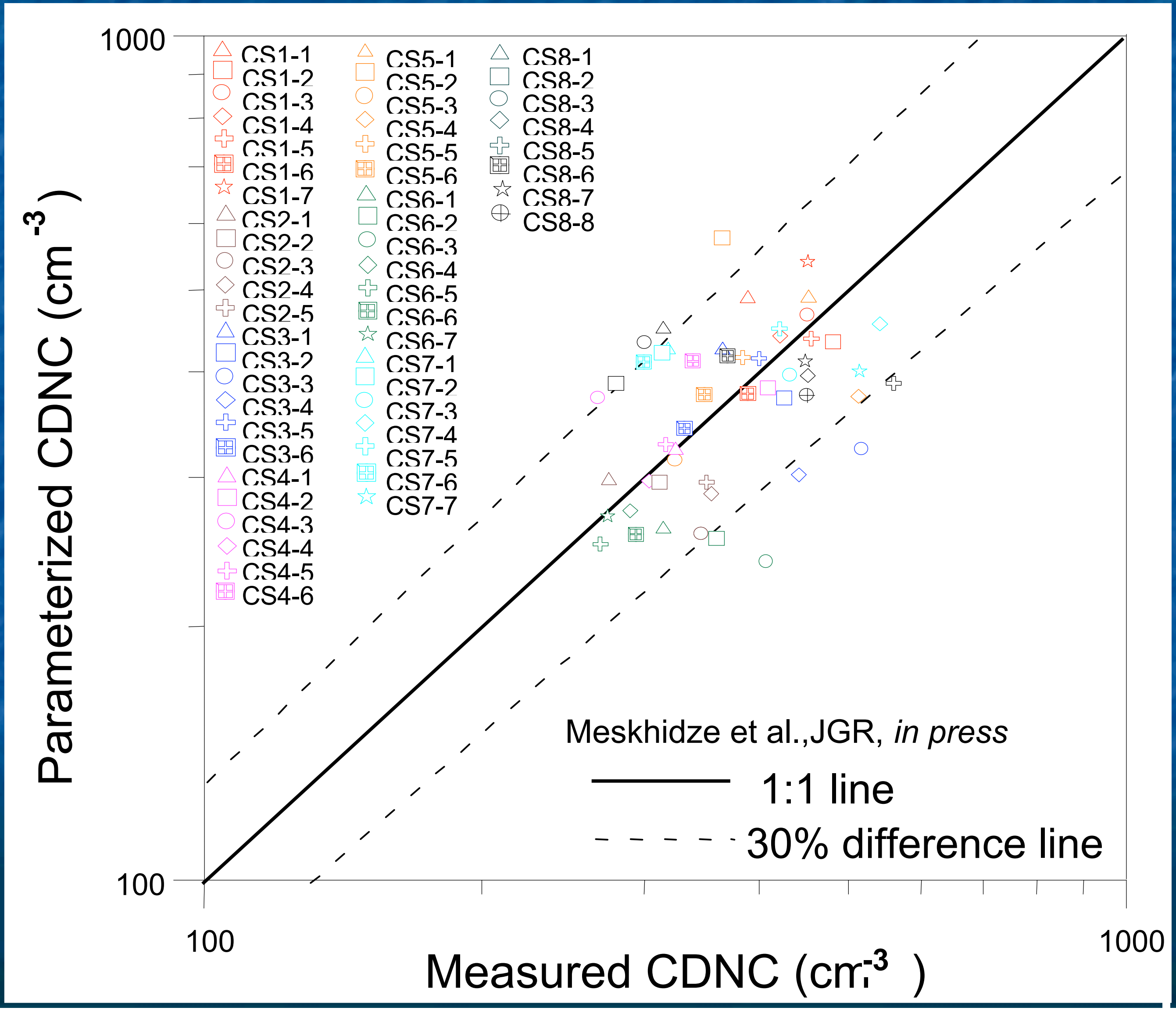
Parameterization agrees with observed CDNC within experimental uncertainty

Single updraft sufficient to describe CDNC

α~ 0.03 – 0.08 within updraft uncertainty

CSTRIPE Evaluation
Coastal Stratocumulus

CIRPAS Twin Otter



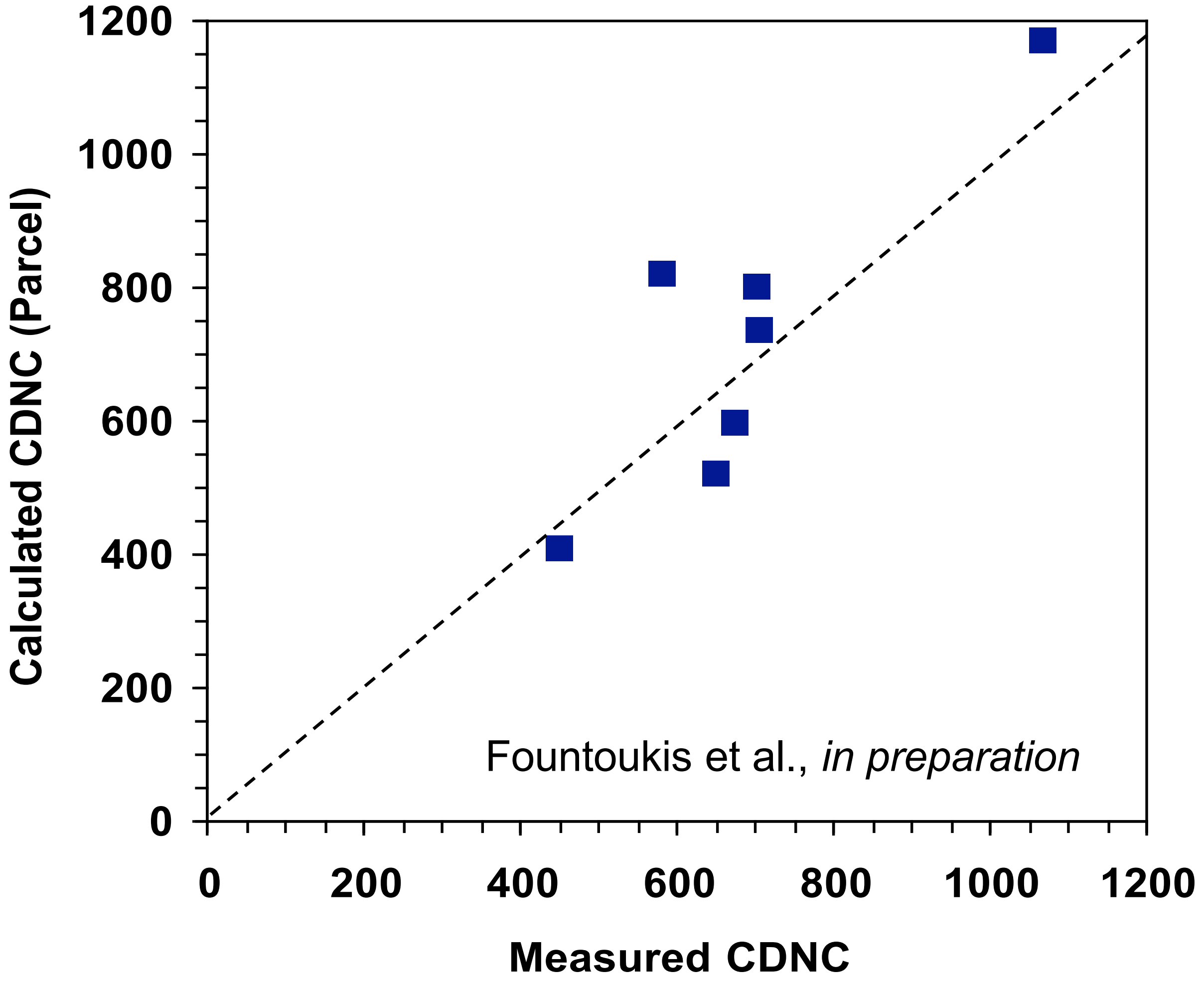
Parameterization agrees with observed CDNC

Gaussian PDF of updraft velocity is sufficient to capture CDNC

Single updraft captures almost as well, with larger uncertainty

ICARTT Evaluation Continental Stratus

CIRPAS Twin Otter

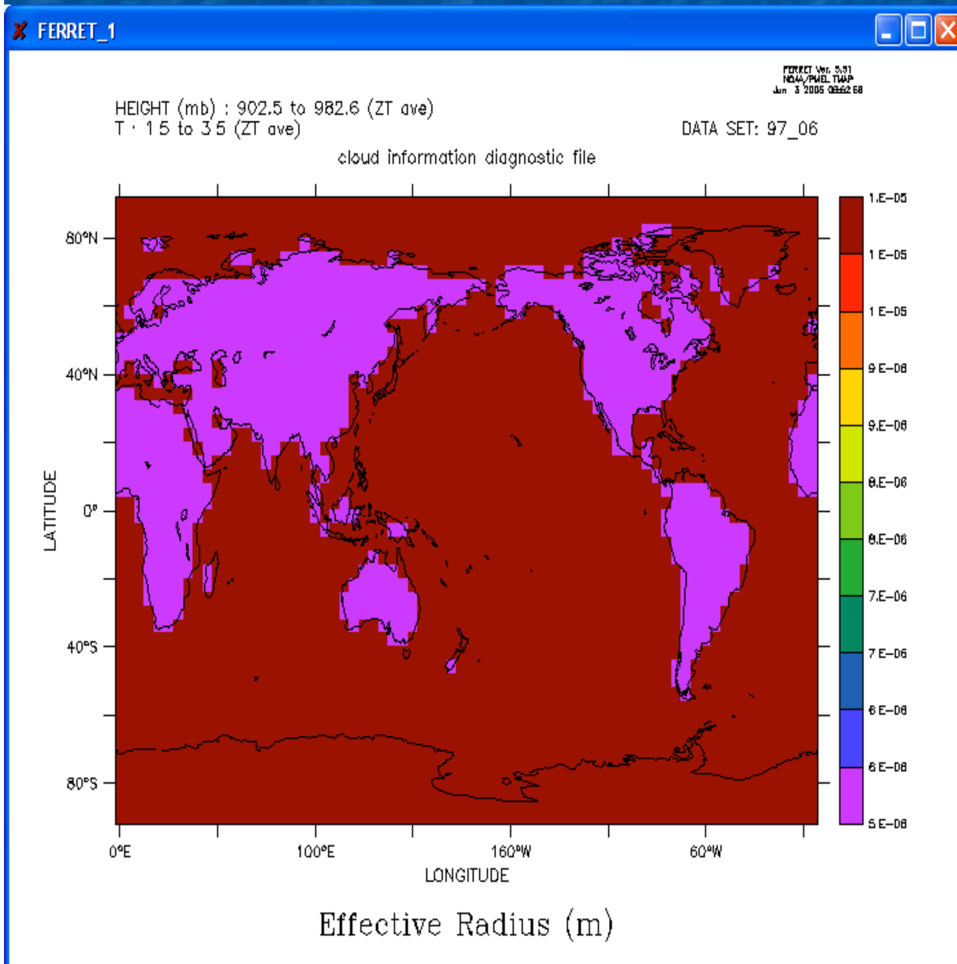


Downwind of power plant south of Detroit on stratus clouds extending over Lake Erie.

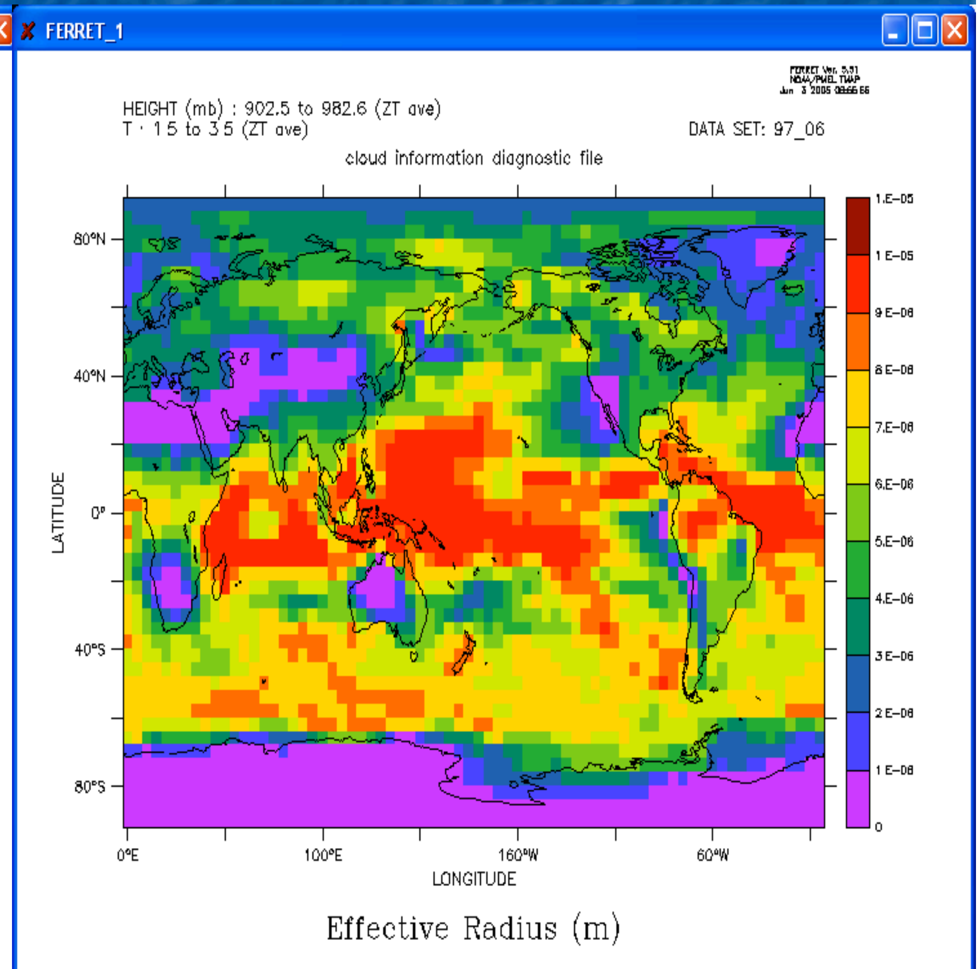
Implications of this work for other GMI efforts

Effective Radius used in photochemistry

Default scheme



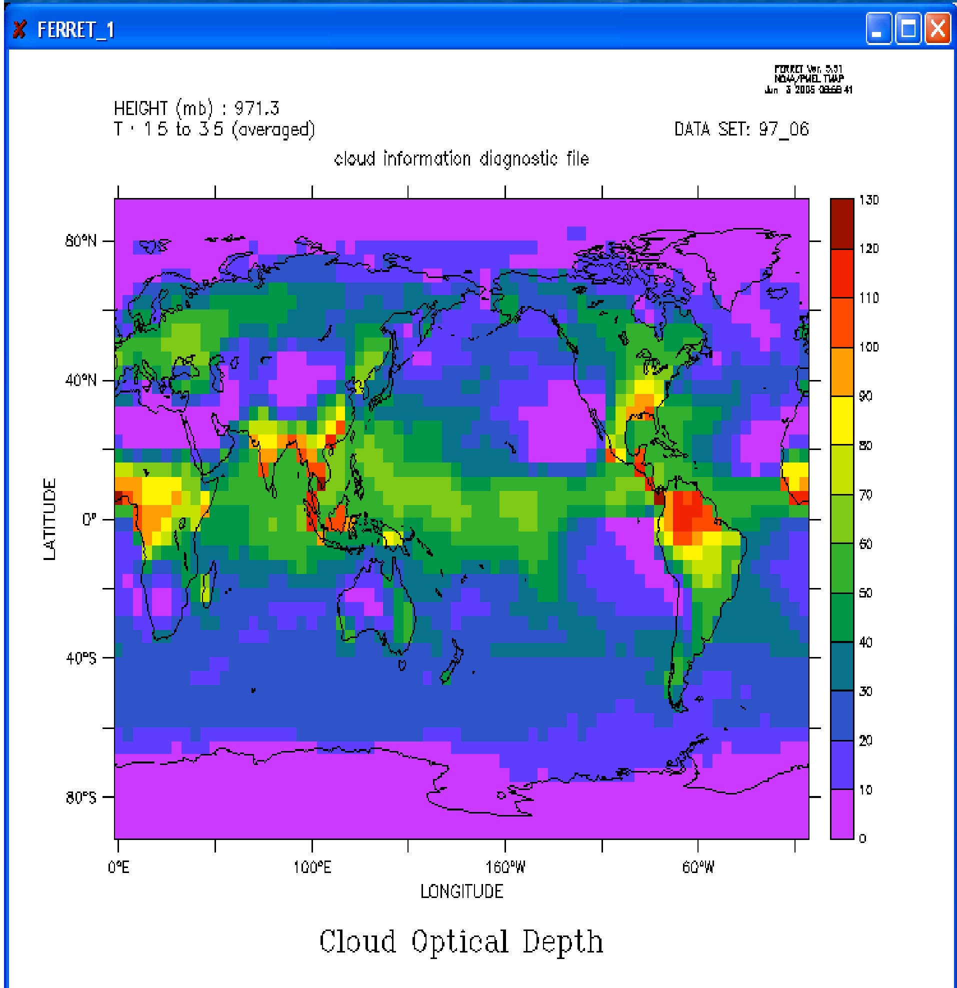
What we calculate



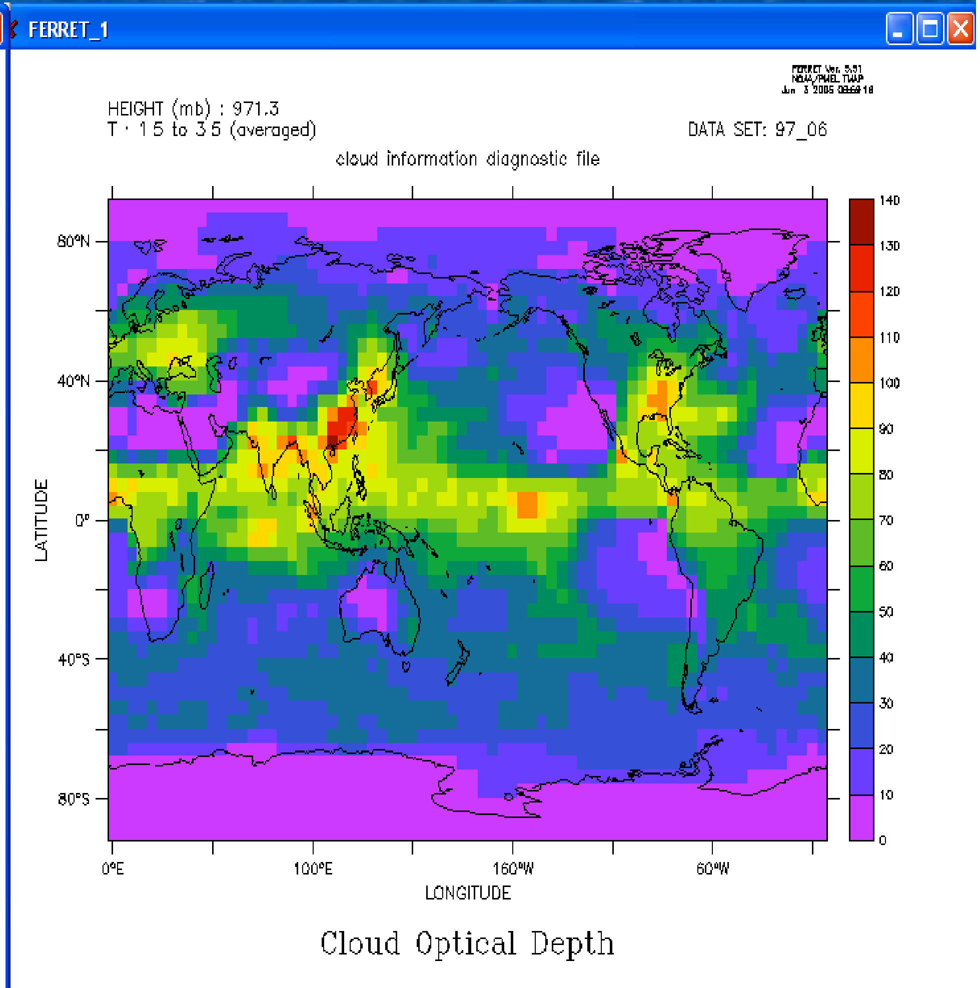
Implications of this work for other GMI efforts

Cloud optical depth used in photochemistry

Default scheme



What we calculate



Cloud optical depth different in anthropogenicaly influenced regions